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Supporting Information for

Consistent decrease in North Atlantic Tropical Cyclone frequency following major volcanic eruptions in the last 3 centuries

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Introduction

This supporting information firstly provides a table (Table S1) with all the Statistical Analysis and results for each category of volcanic eruptions according to the Tropical Cyclone databases and volcanic forcing indices used in this study. Secondly, we include Figure S1, which shows the Percentage of TCs formed in the MDR relative to the whole North Atlantic Basin in the years before and after stratospheric volcanic aerosol forcing. Figure S2 shows the changes in the median number of US Hurricane Landfalls in the years before and after major volcanic eruptions, and Figure S3 shows the changes in Sea Surface Temperatures over the Mean Development Region between pre and post-eruption hurricane seasons. The methodology of the results presented in Figure S3 is explained in Text S1.

HURDAT2 (TC counts) $\bar{x}$=9 ; μ=9.3

GAO08	All	Low Latitude	Low Latitude (SAOD > 0.05)	High Latitude
Number of eruptions	7	4	4	3
Mean (pre/post)	9.10 / 7.52	9.67 / 7.42	9.67 / 7.42	8.33 / 7.67
Median (pre/post)	10.00 / 7.00	11.00 / 7.50	11.00 / 7.50	9.00 / 7.00
p-value (Wilcoxon Rank-Sum Test)	0.071	0.049	0.049	0.41
p-value (Student T-Test)	--	0.034	0.034	0.34
ST93				
Number of eruptions	10	9	6	1
Mean (pre/post)	9.00 / 7.47	9.15 / 7.78	8.83 / 7.00	7.67 / 4.67
Median (pre/post)	8.50 / 7.00	9.00 / 8.00	8.50 / 6.00	6.00 / 6.00
p-value (Wilcoxon Rank-Sum Test)	0.032	0.045	0.041	--
p-value (Student T-Test)	--	--	0.033	--
CU13				
Number of eruptions	7	6	6	1
Mean (pre/post)	8.91 / 6.86	9.11 / 7.22	9.11 / 7.22	7.67 / 4.67
Median (pre/post)	8.00 / 6.00	8.50 / 6.50	8.50 / 6.50	6.00 / 6.00
p-value (Wilcoxon Rank-Sum Test)	0.02	0.027	0.027	--
p-value (Student T-Test)	0.013	0.023	0.023	--

US Hurricane Landfall (Hurricane counts) $\bar{x}$=2 ; μ=1.78

GAO08	All	Low Latitude	Low Latitude (SAOD > 0.05)	High Latitude
Number of eruptions	7	4	4	3
Mean (pre/post)	1.76 / 1.38	1.58 / 1.08	1.58 / 1.08	2.00 / 1.78
Median (pre/post)	2.00 / 1.00	1.50 / 1.00	1.50 / 1.00	2.00 / 2.00
p-value (Wilcoxon Rank-Sum Test)	0.141	0.146	0.146	0.446
p-value (Student T-Test)	--	--	--	--
ST93				
Number of eruptions	10	9	6	1
Mean (pre/post)	1.67 / 1.17	1.52 / 1.11	1.5 / 1.17	3.00 / 1.67
Median (pre/post)	1.00 / 1.00	1.00 / 1.00	1.00 / 1.00	2.00 / 2.00
p-value (Wilcoxon Rank-Sum Test)	0.064	0.111	0.195	--
p-value (Student T-Test)	--	--	--	--
CU13				
Number of eruptions	7	6	6	1
Mean (pre/post)	1.86 / 1.05	1.67 / 0.94	1.67 / 0.94	3.00 / 1.67
Median (pre/post)	2.00 / 1.00	2.00 / 1.00	2.00 / 1.00	2.00 / 2.00
p-value (Wilcoxon Rank-Sum Test)	0.017	0.029	0.029	--
p-value (Student T-Test)	--	--	--	--

HURDAT2 ADJUSTED (TC counts)

GAO08	All	Low Latitude	Low Latitude (SAOD > 0.05)	High Latitude
Number of eruptions	7	4	4	3
Mean (pre/post)	10.12 / 8.46	10.52 / 8.26	10.52 / 8.26	9.59 / 8.73
Median (pre/post)	11.00 / 8.00	11.00 / 7.67	11.00 / 7.67	9.65 / 8.47
p value (Wilcoxon Rank-Sum Test)	0.058	0.037	0.037	0.365
p value (Student T-Test)	0.044	0.024	0.024	0.315
ST93				
Number of eruptions	10	9	6	1
Mean (pre/post)	10.21 / 8.59	10.37 / 8.93	10.31 / 8.39	8.64 / 5.54
Median (pre/post)	10.48 / 8.00	10.73 / 8.00	10.62 / 7.78	6.94 / 6.58
p value (Wilcoxon Rank-Sum Test)	0.034	0.05	0.025	--
p value (Student T-Test)	--	--	0.015	--
CU13				
Number of eruptions	7	6	6	1
Mean (pre/post)	10.31 / 8.17	10.59 / 8.61	10.59 / 8.61	8.64 / 5.54
Median (pre/post)	11.00 / 7.87	11.00 / 8.00	11.00 / 8.00	6.94 / 6.58
p value (Wilcoxon Rank-Sum Test)	0.021	0.029	0.029	--
p value (Student T-Test)	0.008	0.014	0.014	--

CD08 (TC counts) $\bar{x}$=2 ; μ=1.77

GAO08	All	Low Latitude	Low Latitude (SAOD > 0.05)	High Latitude
Number of eruptions	18	10	9	8
Mean (pre/post)	1.93 / 1.39	2.10 / 1.57	2.11 / 1.63	1.71 / 1.17
Median (pre/post)	2.00 / 1.00	2.00 / 1.00	2.00 / 1.00	2.00 / 1.00
p-value (Wilcoxon Rank-Sum Test)	0.006	0.034	0.061	0.037
p-value (Student T-Test)	--	--	--	--
ST93				
Number of eruptions	10	9	6	1
Mean (pre/post)	1.77 / 1.13	1.85 / 1.22	1.89 / 1.33	1 / 0.33
Median (pre/post)	2.00 / 1.00	2.00 / 1.00	2.00 / 1.00	0.00 / 0.00
p-value (Wilcoxon Rank-Sum Test)	0.04	0.044	0.091	--
p-value (Student T-Test)	--	--	--	--
CU13				
Number of eruptions	14	11	11	3
Mean (pre/post)	1.86 / 1.43	1.94 / 1.64	1.94 / 1.64	1.56 / 0.67
Median (pre/post)	2.00 / 1.00	2.00 / 1.00	2.00 / 1.00	2.00 / 1.00
p-value (Wilcoxon Rank-Sum Test)	0.049	0.156	0.156	0.081
p-value (Student T-Test)	--	--	--	--

TCs formed over the MDR (%)

GAO08	All	Low Latitude	Low Latitude (SAOD > 0.05)	High Latitude
Number of eruptions	7	4	4	3
Mean (pre/post)	31.15 / 23.47	37.90 / 27.07	37.90 / 27.07	22.15 / 18.67
Median (pre/post)	30.00 / 23.08	40.83 / 24.04	40.83 / 24.04	20.00 / 16.67
p-value (Wilcoxon Rank-Sum Test)	0.065	0.039	0.039	0.252
p-value (Student T-Test)	0.082	0.07	0.07	0.326
ST93				
Number of eruptions	10	9	6	1
Mean (pre/post)	32.88 / 23.56	34.12 / 25.56	35.37 / 26.10	21.67 / 5.56
Median (pre/post)	36.93 / 18.33	37.50 / 22.22	38.75 / 24.04	16.67 / 0.00
p-value (Wilcoxon Rank-Sum Test)	0.013	0.02	0.023	--
p-value (Student T-Test)	0.02	0.035	0.054	--
CU13				
Number of eruptions	7	6	6	1
Mean (pre/post)	32.46 / 22.67	34.26 / 25.52	34.26 / 25.52	21.67 / 5.56
Median (pre/post)	36.36 / 16.67	38.18 / 21.54	38.18 / 21.54	16.67 / 0.00
p-value (Wilcoxon Rank-Sum Test)	0.029	0.042	0.042	--
p-value (Student T-Test)	0.04	0.069	0.069	--

SSTs (°C) over the MDR

GAO08	All	Low Latitude	Low Latitude (SAOD > 0.05)	High Latitude
Number of eruptions	7	4	4	3
Mean (pre/post)	27.12 / 27.04	27.25 / 27.02	27.25 / 27.02	26.94 / 27.05
Median (pre/post)	27.22 / 27.07	27.28 / 27.06	27.28 / 27.06	26.86 / 27.07
p value (Wilcoxon Rank-Sum Test)	0.165	0.006	0.006	--
p value (Student T-Test)	--	0.006	0.006	--
ST93				
Number of eruptions	9	8	5	1
Mean (pre/post)	27.11 / 26.96	27.15 / 27.01	27.19 / 26.96	26.77 / 26.63
Median (pre/post)	27.09 / 26.91	27.15 / 27.05	27.23 / 26.89	26.71 / 26.70
p value (Wilcoxon Rank-Sum Test)	0.025	0.021	0.006	--
p value (Student T-Test)	0.022	0.02	0.005	--
CU13				
Number of eruptions	6	5	5	1
Mean (pre/post)	27.12 / 26.91	27.19 / 26.96	27.19 / 26.96	26.77 / 26.63
Median (pre/post)	27.16 / 26.87	27.23 / 26.89	27.23 / 26.89	26.71 / 26.70
p value (Wilcoxon Rank-Sum Test)	0.011	0.006	0.006	--
p value (Student T-Test)	0.009	0.005	0.005	--

Table S1. Statistical Analysis

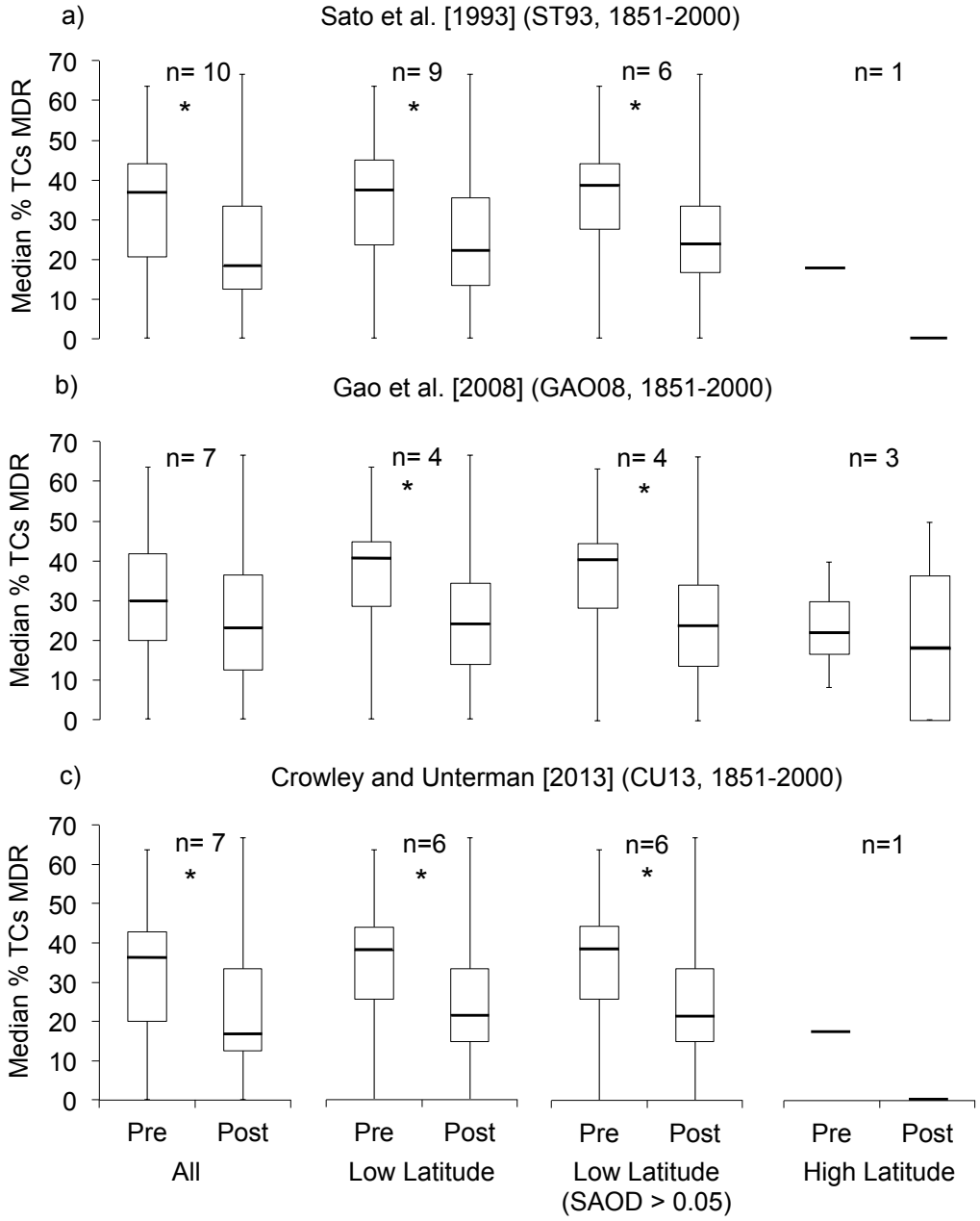

Figure S1. Percentage of TCs formed in the MDR relative to the whole North Atlantic Basin in the years before and after stratospheric volcanic aerosol forcing by major volcanic eruptions, according to volcanic forcing indices a) *Sato et al*. [1993]; b) *Gao et al*. [2008], and c) *Crowley and Unterman* [2013]. Four categories of eruptions are considered, *All*, *Low Latitude*, *Low Latitude (SAOD > 0.05)* and NH *High Latitude*, and 'n' indicates the number of eruptions in each category. The box plot outlines the median, 25 and 75% quartiles and range of TC counts for each population; only the median is displayed if n=1. An '*' asterisk denotes a statistically significant decrease in TCs between pre- and post-eruption years at p-value < 0.05 (Wilcoxon Rank-Sum test; full statistics given in Table S1).

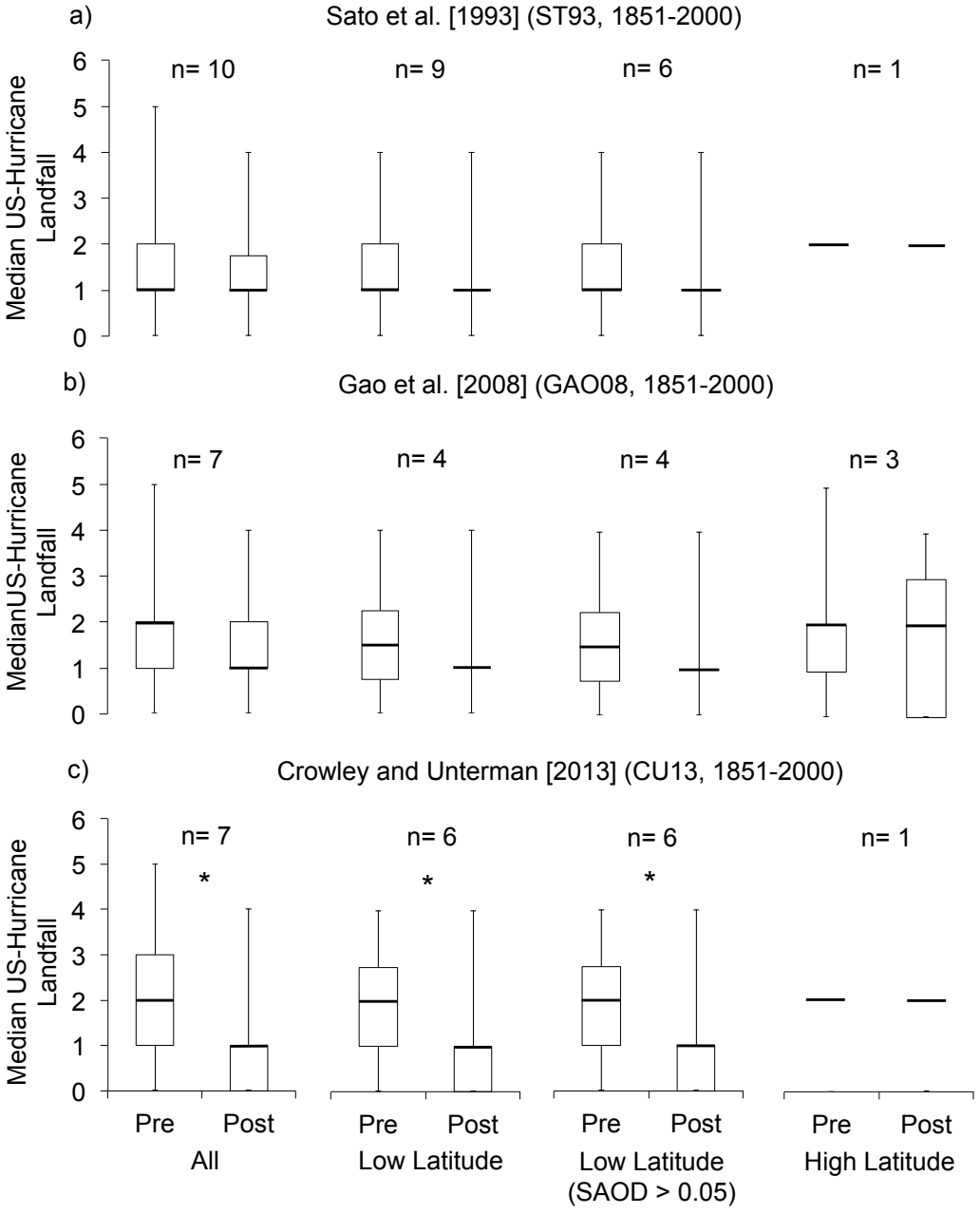

Figure S2. Changes in the median number of US Hurricane Landfalls [*Landsea et al*., 2004; *Landsea and Franklin*, 2013] in the years before and after stratospheric volcanic aerosol forcing by major volcanic eruptions, according to volcanic forcing indices a) *Sato et al*. [1993]; b) *Gao et al*. [2008], and c) *Crowley and Unterman* [2013]. Four categories of eruptions are considered, *All*, *Low Latitude*, *Low Latitude (SAOD > 0.05)* and NH *High Latitude*, and 'n' indicates the number of eruptions in each category. The box plot outlines the median, 25 and 75% quartiles and range of hurricane counts for each population; only the median is displayed if n=1. An '*' asterisk denotes a statistically significant decrease in US hurricane landfalls between pre- and post-eruption years at p-value < 0.05 (Wilcoxon Rank-Sum test; full statistics given in Table S1).

Text S1. Impact of volcanic eruptions on Sea Surface Temperatures (SST)

We determined decreases in the averaged SSTs over the MDR between the months of June to November (hurricane season) of the three pre-eruption years and the three post-eruption years for each category of volcanic eruptions included in this study. We used monthly interpolated 1° gridded SSTs from the HadISST1 database for 8°N-20°N, 20°W-65°W [1871-present; *Rayner et al*., 2003] and considered volcanic events after 1871.

Averaged SSTs (June-November) over the MDR were significantly lower (p-value < 0.05) by 0.14° to 0.23°C after *All*, *Low Latitude* and *Low Latitude (SAOD > 0.05)* eruptions in the ST93 and the CU13 volcanic forcing indices, and for *Low Latitude* and *Low Latitude (SAOD > 0.05)* in the GAO08 volcanic forcing index (Figure SI.3). No decrease was found for *High Latitude* volcanic eruptions, but this test was limited due to the small number of events.

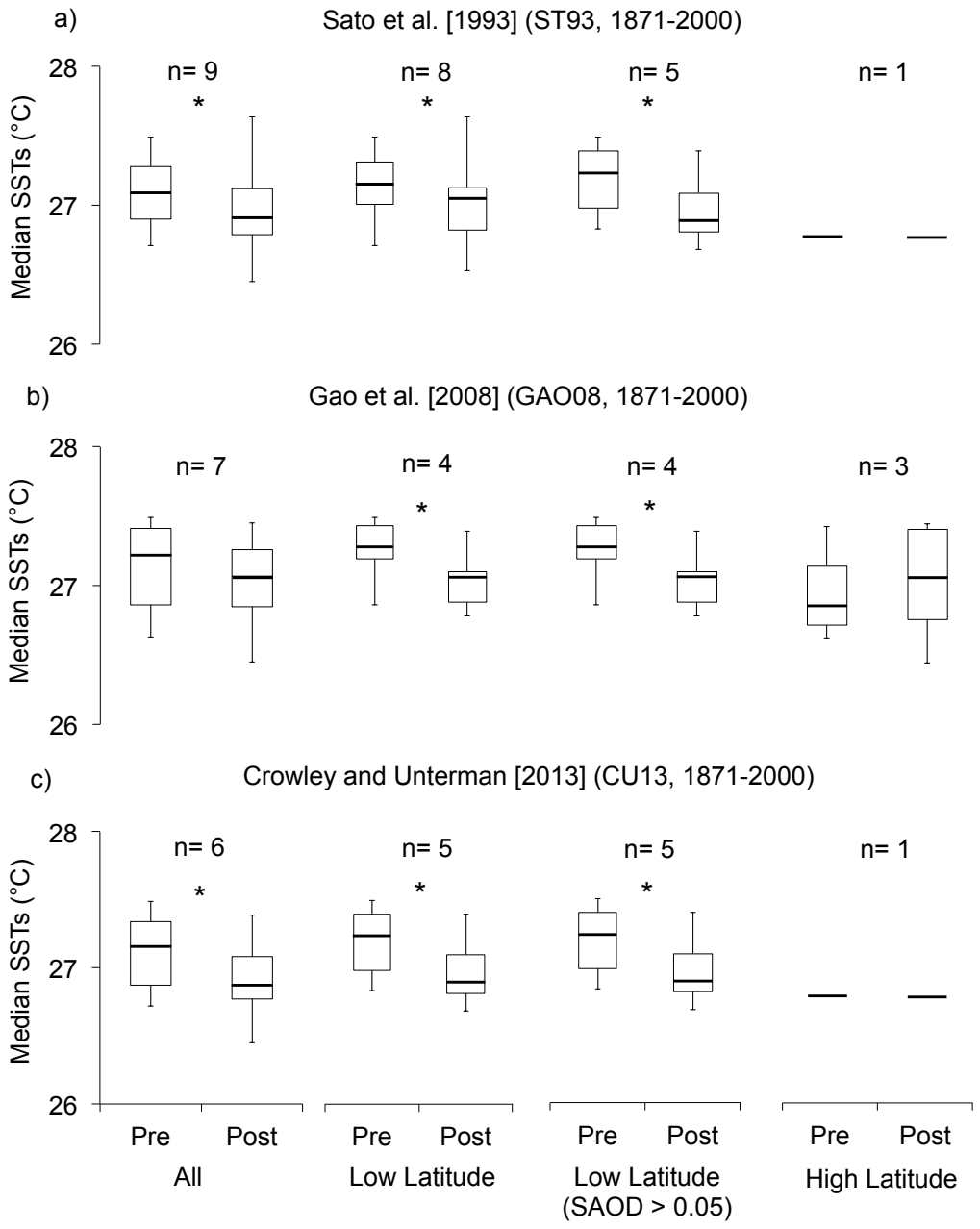

Figure S3. Changes in Sea Surface Temperatures over the Mean Development Region (defined as 8ºN-20ºN, 20ºW-65ºW) between pre-eruption hurricane seasons (June-November) and post eruption hurricane seasons according to a) *Sato et al*. [1993], b) *Gao et al*. [2008], and c) *Crowley and Unterman* [2013] volcanic forcing indices. Only the median is shown if n=1 eruptions. An '*' asterisk denotes a statistically significant decrease in MDR SSTs between pre and post eruption years at p-value < 0.05 (Wilcoxon Rank-Sum test; full statistics given in Table S1).

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